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Full Length Research Paper

Statistical and trend analyses of rainfall in Sokoto

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Sokoto is in the North West geopolitical zone of Nigeria. The major occupation of the people in this city is farming, which depends on rainfalls. This article presents statistical and trend analyses of the rainfall in Sokoto. Rainfall data in the city for a period of 1915- 2008 were collected from archives. The existence of trend and sequence of rainfalls were established using non-parametric techniques. The study revealed that overall averages of yearly and monthly total rainfall were 726±24.03 mm and 61.75±25.31 mm respectively. Yearly total, mean, maximum and minimum rainfalls have Mann-Whitney of 42, 57, 67 and 37 between 1947and 1977 with 43, 66, 60 and 107 in the period between 1978 and 2008. Sen.'s estimator revealed that there are significant upward trends for yearly total (10.08mm/year), yearly mean (8.14 mm/year), maximum (6.84 mm/year) and minimum (10.72 mm/year) within a period of 1947 – 1977 and significant downward trends for yearly total (9.94mm/year), yearly mean (6.97 mm/year) and maximum (7.75 mm/year) within a period of 1978 – 2008. It was concluded that there is a significant downward trend in the yearly total and mean rainfalls at Sokoto in the last three decades (30years), which can be attributed to climate change.

Keywords: Rainfall, Trend analysis, Statistical methods, Non-parametric techniques, upward trend.

INTRODUCTION

Climate change seems to be the foremost global challenge facing humans at the moment. The scientific community has not been left out as the causes and the solutions climate change. One of the indicators of climate change is increase or decrease in rainfall (Obot et al., 2010). Rainfall is a climate parameter that affects the way and manner man lives. It affects every facet of the ecological system, flora and fauna inclusive. Globally, lots of studies have been conducted on rainfall. Obot et al. (2010) presented total amount of rainfall across Nigeria in selected locations in each of the six geopolitical zones within a 30 years period (1978-2007) and the study reveals an increasing trend in only one out of the six locations. Abaje et al. (2010) worked on an analysis of rainfall trends in Kafanchan, Kaduna State, Nigeria. It was stated that government policies in Nigeria should be based on recent rainfall trends.

Sokoto is in Sokoto state, which is in North West geopolitical zone of Nigeria. The state has a population 3,696,999; population density of 133 people per km^2 and catchment of 27,825 km^2 (Figure 1, Dada et al., 2007). The climate is semiarid with a zone of savannah-type vegetation as part of the sub-Saharan Sudan belt of West Africa. Farming is the major occupation in the place. It is well known that crop production in semi-arid regions is largely determined by climatic and soil factors. These show that a detailed knowledge of rainfall regime is an important prerequisite for agricultural planning and that there are needs to obtain the trend of rainfall in the entire region in Nigeria. The purpose of this study is to: characterize trend of total amount of rainfall in Sokoto and sequence of the rainfalls.

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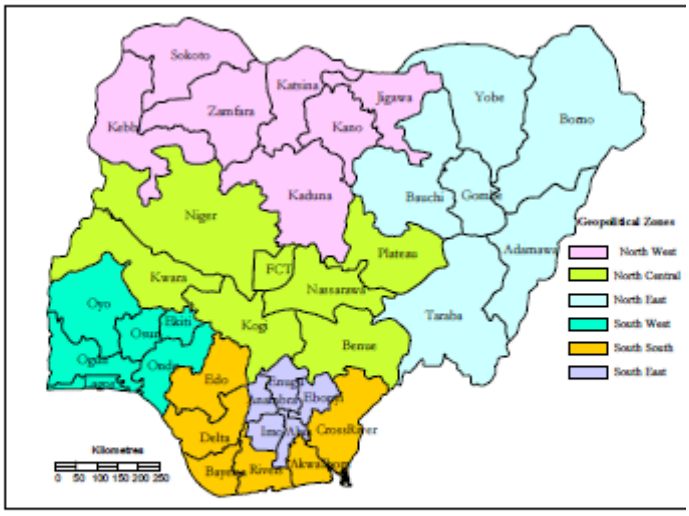

Figure 1. Map of Nigeria showing all the states and six geopolitical zones

MATERIALS AND METHOD

Information on rainfall (1915 to 2008) in Sokoto were collected from literature such as Akintola (1986), institutions, local government headquarters, state and Federal government archives (Ministry of Water Resources; Nigerian Meteorological Agency (NIMET) Abuja; etc). The data were analysed using non-parametric analyses with a particular attention to trend of the rainfall over the years.Slopes(S) of the existence trend and sequence were determined using Sen.'s estimator and overall slopes (Tan (β +α +φ) were computed as follows:

$$S = \frac{R_A - R_B}{N_A - N_B} \quad (1)$$

$$Tan(\alpha + \beta + \phi) = \frac{Tan\alpha + \dfrac{Tan\beta + Tan\phi}{1 - Tan\beta * Tan\phi}}{1 - Tan\alpha + \dfrac{Tan\beta + Tan\phi}{1 - Tan\beta * Tan\phi}} \quad (2)$$

RESULT AND DISCUSSION

Result of this study is discussed in the following categories: statistical summary of rainfall (annual mean precipitation); monthly rainfall trend and sequential analyses.

Statistical Summary

Table 1 presents yearly total, yearly mean, median, maximum, minimum and standard deviation (SD) of the rainfall for all years (1915 – 2008). The table shows spatial distribution of the rainfall. From the table yearly total rainfall has a decreasing trend with the strongest downward magnitude in the group 1978 – 2008. The same trends were observed for the yearly mean, median and yearly minimum rainfalls. These trends show that there is a decline in the magnitude of rainfall in the city which can be attributed to climate change as highlighted in Odjugo (2009; 2010); Adelana et al(2006). From these literature (Odjugo, 2009; 2010); Adelana et al., 2006), between 1901 and 1935 the temperature change was 0.5^0C (28 – 28.5 ^{o}C) for the region; between 1936 and 1970 the temperature change was 0.5^0C (28.5 – 29 ^{o}C) and between 1971 and 2006 the temperature change was 0.5^0C (29 – 29.5 ^{o}C). All these show that there is an increase in temperature (1.5^oC), while the total yearly rainfall dropped from 736.3 mm to 632.6 mm, a drop from 105.8 mm to 53.5 mm in the monthly mean with a drop from 245.1 mm to 171.4 mm in the monthly maximum. It shows that there are drops of 69.13 mm / ^{o}C; 34.67 mm / ^{o}C and 49.13 mm / ^{o}C for total yearly rainfall, monthly mean and monthly maximum rainfalls respectively.

Monthly Rainfalls

Table 1 presents monthly mean, median, maximum and

Table 1. Statistical summary of yearly total rainfall in Sokoto

Year	**1915**	**1916**	**1917**	**1918**	**1919**	**1920**	**1921**	**1922**	**1923**	**1924**	**1925**	**1926**	**1927**	**1928**	**1929**	**1930**	
Total Rainfall (mm)	736.3	488.9	711.0	900.9	683.4	626.5	1130.6	569.9	864.8	914.9	370.6	763.0	604.5	620.3	913.2	792.2	
Mean (mm)	105.8	41.2	59.5	75.2	57.3	52.4	99.9	47.6	73.3	77.4	31.5	71.8	51.6	52.4	76.5	66.2	
Maximum	245.11	135.13	273.05	317.50	330.96	242.32	307.09	191.52	278.13	311.51	149.61	190.50	230.38	202.95	237.49	239.78	
Minimum	1.52	1.70	2.98	1.52	3.81	2.03	24.38	0.51	15.24	6.60	4.32	55.37	14.99	8.39	4.70	2.63	
Median	99.31	84.07	107.44	145.80	36.83	96.01	159.26	79.50	72.14	105.41	30.99	122.68	82.80	99.82	124.21	132.34	
SD	89.8	54.7	100.3	112.5	120.9	85.4	111.8	80.9	108.1	122.6	58.6	46.8	73.0	66.2	82.4	77.6	
Year	**1931**	**1932**	**1933**	**1934**	**1935**	**1936**	**1937**	**1938**	**1939**	**1940**	**1941**	**1942**	**1943**	**1944**	**1945**	**1946**	**1947**
Rainfall (mm)	667.5	753.3	627.4	794.1	1005.1	894.3	665.7	654.5	741.2	551.4	557.0	695.8	699.2	731.9	746.5	1268.2	811.1
Mean	55.9	62.8	53.4	66.8	84.1	76.6	55.5	54.6	61.8	46.5	46.7	58.1	58.4	61.1	62.7	105.7	55.9
Maximum	260.60	278.64	191.01	322.83	475.00	361.19	293.88	312.42	296.67	158.24	180.59	245.62	242.06	249.17	247.20	355.10	276.90
Minimum	3.05	0.51	13.21	7.40	0.51	24.13	0.51	0.29	0.25	6.35	3.56	1.99	1.52	0.85	5.60	0.50	7.40
Median	78.23	95.50	86.36	96.72	137.92	102.62	39.16	86.11	86.11	95.50	85.04	64.36	76.20	51.95	37.10	234.20	95.30
SD	92.3	102.7	72.0	106.8	167.0	118.7	105.5	109.6	100.7	58.4	64.6	88.8	100.9	109.3	111.2	157.3	92.3
Year	**1948**	**1949**	**1950**	**1951**	**1952**	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**	**1960**	**1961**	**1962**	**1963**	**1964**
Rainfall (mm)	998.7	1118.6	990.0	719.4	985.6	781.5	1128.0	762.7	980.4	959.4	899.8	637.5	1007.9	630.0	512.5	874.1	973.0
Mean	68.2	92.0	98.1	85.2	61.7	82.7	68.3	97.1	65.3	82.8	81.2	76.3	53.7	84.2	53.1	43.1	73.0
Maximum	355.60	398.27	442.00	198.80	355.20	167.70	509.50	253.70	306.10	246.60	297.40	318.50	270.50	199.00	188.50	247.70	325.80
Minimum	26.21	29.35	27.40	11.70	6.55	20.30	36.60	15.70	3.60	11.90	8.10	7.11	2.30	2.53	4.10	2.30	1.29
Median	153.60	172.03	149.60	86.90	174.10	139.20	97.68	110.50	79.80	178.10	182.10	65.50	133.70	82.30	84.90	117.00	136.40
SD	106.4	114.7	134.7	147.5	80.6	128.8	61.6	167.3	95.1	139.2	113.8	117.6	110.1	125.4	82.9	65.6	88.1
Year	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
Rainfall (mm)	825.6	703.1	635.7	476.2	771.1	900.8	662.7	536.6	484.0	559.6	614.3	827.6	755.8	711.2	614.3	550.3	570.0
Mean	69.8	58.9	57.4	41.4	65.2	75.6	56.7	46.5	40.5	47.0	51.2	69.0	63.2	59.4	51.6	46.5	49.6
Maximum	320.00	174.50	253.20	134.40	214.40	306.00	292.90	131.30	127.50	175.50	147.30	186.00	334.90	244.00	265.40	192.90	208.40
Minimum	4.80	3.30	1.00	20.10	11.26	3.60	3.64	4.10	0.50	3.80	0.30	0.77	0.50	1.53	5.45	7.20	13.05
Median	126.70	140.20	124.20	51.30	100.30	99.80	65.50	72.40	69.00	104.10	109.20	114.30	123.40	134.20	67.20	59.30	76.20
SD	112.6	67.7	89.2	50.2	93.0	135.4	100.6	48.9	57.6	66.1	55.6	67.9	115.4	85.4	92.9	69.0	67.4
Year	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Rainfall (mm)	569.1	629.7	478.4	438.1	487.4	342.2	735.5	585.8	671.0	740.2	561.2	649.6	823.5	507.1	702.3	640.9	835.9
Mean	50.8	54.3	40.7	37.0	42.2	32.8	61.8	50.5	56.7	64.3	48.5	54.5	69.1	42.5	58.8	53.8	70.5

Table 1 Continued

Table 1. Continue

Maximum	300.30	229.40	125.40	135.10	151.30	130.50	227.90	192.50	347.40	211.30	164.80	238.20	355.60	200.50	240.90	175.70	374.90
Minimum	6.00	11.23	10.21	5.31	11.64	4.50	5.04	16.60	9.42	12.10	12.25	5.00	5.50	2.40	3.02	1.80	1.70
Median	39.99	62.20	95.20	71.70	36.40	49.10	107.30	60.00	71.30	117.00	61.90	54.80	61.38	23.70	49.00	112.80	88.70
SD	107.3	80.1	51.2	49.4	62.6	40.4	91.5	73.3	115.6	75.0	64.6	93.2	126.5	83.2	95.7	70.6	136.9
Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**							
Rainfall (mm)	711.6	720	756.7	754.4	869.8	686.6	632.6	739.5	663.0	618.7							
Mean	60.2	61.0	65.1	68.2	74.7	58.1	53.8	62.8	55.8	52.8							
Maximum	304.30	361.60	360.80	231.60	288.70	296.50	171.10	314.70	235.60	235.79							
Minimum	11.20	12.54	24.10	30.80	17.50	8.90	3.50	13.92	6.60	15.34							
Median	45.00	59.70	60.50	67.40	71.30	70.96	104.50	40.60	65.90	84.75							
SD	104.4	122.8	117.5	82.7	113.6	98.1	64.2	113.7	84.2	74.8							
Monthly	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**					
Mean	0.03	0.06	1.65	13.07	47.80	126.81	174.94	224.04	127.41	25.11	0.09	0.00					
Maximum	3.00	3.00	33.30	105.10	154.43	355.10	361.60	509.50	374.90	114.30	8.90	0.00					
Minimum	0.03	0.06	1.65	0.25	0.50	9.91	56.80	67.20	20.30	0.50	0.09	0.00					
Median	0.00	0.00	0.00	7.30	40.15	122.05	162.35	207.13	115.78	17.54	0.00	0.00					

Table 2. Non parameter test of summarised statistical data

Group	Year	Mean Rank				Sum of Rank				Number of samples
		Total	Mean	Maximum	Minimum	Total	Mean	Maximum	Minimum	
A	1915-1930	18.13	15.33	15.67	13.33	272	230	235	200	15
	1931-1946	14.00	16.63	16.31	18.80	224	266	261	296	16
B	1947-1961	12.97	11.80	10.80	10.47	187	177	162	157	15
	1962-1977	19.31	19.94	20.88	21.19	309	319	334	339	16
C	1978- 1992	20.00	19.60	21.13	16.90	300	294	317	254	15
	1993-2008	12.25	12.63	11.19	15.10	197	202	179	243	16

minimum rainfalls in the city. The table revealed that the rainy period in Sokoto is between April and October, with June, July, August and September as significant rainy months. The month August has the highest magnitude of monthly rainfall follows by July, September and June in decreasing order. This shows that for farming activities in rainy seasons crops with maximum water demand of six months are the best for the area. Similar results were presented in Adelana et al. (2006) for monthly mean and monthly evaporations.

Trend Analysis

The result of trend analyses are discussed in the following ways: Trend of yearly and monthly rainfalls with the sequences of the monthly and yearly rainfalls.

Table 3. Statistical Tests of summarised statistical data.

Group	Mann- Whitney				Wilcoxon				$Z = \frac{x - \bar{x}}{\sigma}$				Asymptotic Significant (2 tailed)			
	Total	Mean	Maximum	Minimum	Total	Mean	Maximum	Minimum	Total	Mean	Maximum	Minimum	Total	Mean	Maximum	Minimum
A	115	110	88	80	235	207	224	200	-0.20	-0.40	-1.27	-1.58	0.861	0.711	0.206	0.113
B	42	57	67	37	162	177	187	157	-3.08*	-2.49*	-2.10*	-3.28	0.001	0.012	0.036	0.001
C	43	66	60	107	179	230	196	243	-3.04*	-2.14*	-2.31*	-0.53	0.002	0.033	0.017	0.593

*Statistically significant at 95% confidence level

Table 4. Non parameter test of summarised statistical data.

Group	Year	Median Rank				Slope($S = \frac{R_A - R_B}{N_A - N_B}$) mm/year				Kruskal –Wallis (Chi- Squared and p)				Number of samples
		Total	Mean	Maximum	Minimum	Total	Mean	Maximum	Minimum	Total	Mean	Maximum	Minimum	
A	1915-1930	15.67	15.33	18.13	13.33	0.64	1.30	-4.13	5.17	0.04	0.16	1.60	2.51 (Chi)	15
	1931-1946	16.31	16.63	14.00	18.50					0.84	0.69	0.21	0.11 (p)	16
B	1947-1961	10.80	11.80	12.47	10.47	10.08	8.14	6.84	10.72	9.51†	6.20†	4.39†	10.51† (Chi)	15
	1962-1977	20.88	19.94	19.31	21.19					0.002	0.01	0.04	0.001(p)	16
C	1978-1992	21.13	19.60	20.00	16.90	-9.94 (-0.579)*	-6.97 (1.356)*	-7.75 (-4.457)*	-1.74 (-4.130)	9.26†	4.56†	5.63	0.29 (Chi)	15
	1993-2008	11.19	12.63	12.25	15.16					0.002	0.03	0.02	0.59 (p)	16

+Overall slope for the year (trend)

++Statistically significant at 95% confidence level

Table 5. Non parameter test of the monthly rainfall

Month	Group	Year	Mean (median) Rank	Sum of Rank	Mann-Whitney	Wilcoxon	Z	Asymptotic Significant (2 tailed)	Slope($s = \frac{R_A - R_B}{N_A - N_B}$) mm/year	Kruskal – Wallis (Chi-Squared)
April	A	1915-1930	12.70	190.50	70.5	190.5	-1.96	0.05	6.39	3.83†
		1931-1946	19.09	305.50						
	B	1947-1961	12.30	184.50	64.5	184.5	-2.19	0.21	7.19	4.82†
		1962-1977	19.47	311.50						
	C	1978- 1992	14.60	219.00	99	219	-0.83	0.41	2.71 (1.324)*	0.69
		1993-2008	17.31	277.00						
May	A	1915-1930	15.57	233.50	113.5	233.5	-0.26	0.80	0.84	0.07
		1931-1946	16.41	262.50						
	B	1947-1961	17.33	260.00	100	236	-0.80	0.43	-2.54	0.63
		1962-1977	14.75	236.00						
	C	1978- 1992	19.07	286.00	74	210	-1.82	0.07	-5.94(2.917)*	3.31
		1993-2008	13.13	210.00						
June	A	1915-1930	13.47	202.00	82	202	-1.50	0.13	4.91	2.26
		1931-1946	18.38	294.00						
	B	1947-1961	11.80	177.00	57	177	-2.49	0.01	8.14	6.20†
		1962-1977	19.94	319.00						
	C	1978- 1992	15.00	225.00	105	225	-0.59	0.55	1.94 (0.973)*	0.35
		1993-2008	16.94	271.00						
July	A	1915-1930	16.60	249.00	111	247	-0.36	0.72	-1.16	0.13
		1931-1946	15.44	247.00						
	B	1947-1961	12.07	181.00	61	181	-2.33	0.02	7.02	5.44†
		1962-1977	19.69	315.00						
	C	1978- 1992	20.07	301.00	59	195	-2.41	0.02	-7.88(-1.196)*	5.81†
		1993-2008	12.19	195.00						
August	A	1915-1930	16.67	250.00	110	246	-0.40	0.69	-1.29	0.16
		1931-1946	15.38	246.00						
	B	1947-1961	11.43	171.50	51.5	171.5	-2.71	0.01	8.85	7.33†
		1962-1977	20.28	324.50						
	C	1978- 1992	17.20	258.00	102	238	-0.71	0.47	-2.32 (-0.709)*	0.51
		1993-2008	14.88	238.00						
September	A	1915-1930	15.70	235.50	115.5	235.5	-0.18	0.86	0.58	0.03

Table 5. Continue

October	B	1931-1946	16.28	260.50	79.5	199.5	-1.60	0.11	5.23	2.56
		1947-1961	13.30	199.50						
		1962-1977	18.53	296.50						
	C	1978- 1992	16.47	247.00	113	249	-0.23	0.80	-0.91 (2.395)*	0.08
		1993-2008	15.56	249.00						
	A	1915-1930	15.53	233.00	113	233	-0.28	0.78	0.91	0.08
		1931-1946	16.44	263.00						
	B	1947-1961	17.00	255.00	105	241	-0.59	0.55	-1.94	0.35
		1962-1977	15.05	241.00						
	C	1978- 1992	17.27	259.00	101	237	-0.79	0.45	-2.46 (33.82) [1] Overall slope for the month (Trend)	0.56
		1993-2008	14.81	237.00						

Trends of yearly rainfalls

Tables 2, 3 and 4 present results of non-parametric analyses (mean rank, sum of rank; Mann- Whitney, Wilcoxon, standard anomaly index (SAI; Z), median rank, Sen.'s test Kruskal Wallis and Chi- Squared). From these tables it was observed that there are downward trends in the total, mean, maximum and minimum rainfall in the city between 1915 and 1946, but these trends were not statistically significant at 95 % confidence level. Between 1947 and 1977 there are downward trends in the rainfall parameters with SAIs of -3.06; -2.49; -2.10 and -3.28 for total, mean; maximum and minimum rainfalls respectively. Asymptotic significant (probability) of these rainfall parameters were found to be 0.001; 0.0012; 0.036 and 0.001 for total, mean; maximum and minimum rainfalls respectively. SAI provides an area average index of relation rainfall yields based on the standardization of total, mean, maximum and minimum rainfalls. These magnitude of SAI ($Z > 1.96$) and probabilities show that the downward trends are statistically significant at 95 % confidence level. Also the sign ($Z < 0$) revealed that the values were less than expected overall mean rainfall and that there was more dryness in the period between 1947 and 1977 than the period between 1915 and 1946. Sen.'s estimators revealed that yearly total; mean; maximum and minimum were 0.64 mm/year; 1.30 mm/year; -4.30 mm/year and 5.17 mm/year; 10.08 mm/year; 8.14 mm/year; 6.84 mm/year and 10.72 mm/year; and -9.94 mm/year; -6.97 mm/year; -7.75 mm/year and -1.74 mm/year for a period of 1915 – 1946; 1947 – 1977 and 1978 - 2008 respectively. Overall slopes for yearly total; mean; maximum and minimum rainfalls were found to be -0.579 mm/year; 1.356 mm/year; - 4.457 mm/year and -4.130 mm/year respectively. Magnitudes of Chi-squared and Kruskal –Wallis test revealed that these trends are statistically significant, which indicates that there are significant trends in the yearly total; mean; maximum and minimum in the area.

Trends of monthly rainfalls

Table 5 presents result of trend analyses conducted on the monthly rainfall. It provides magnitude of mean rank, sum of rank; Mann-Whitney U, Wilcoxon, standard anomaly index (SAI; Z), median rank, Sen.'s test Kruskal Wallis and Chi- Squared. From the slopes of the trend it was revealed that there were downward trends in rainfall between 1978 and 2008 for all the rainy months. The slopes were 2.71 mm/year; -5.94 mm/year; 1.94 mm/year; -7.88 mm/year; -2.32 mm/year; -0.91 mm/year and -2.46 mm/year for the month April, May, June, July, August September and October respectively. The magnitude of SAI revealed that July, which is among the month with significant rainfalls has statistically significant downward trend in rainfall. Overall slopes of the monthly rainfalls show that there are upward trends in rainfall in the months of April (1.324 mm/year); May (2.917 mm/year); June (0.973 mm/year) and September (2.354 mm/year).

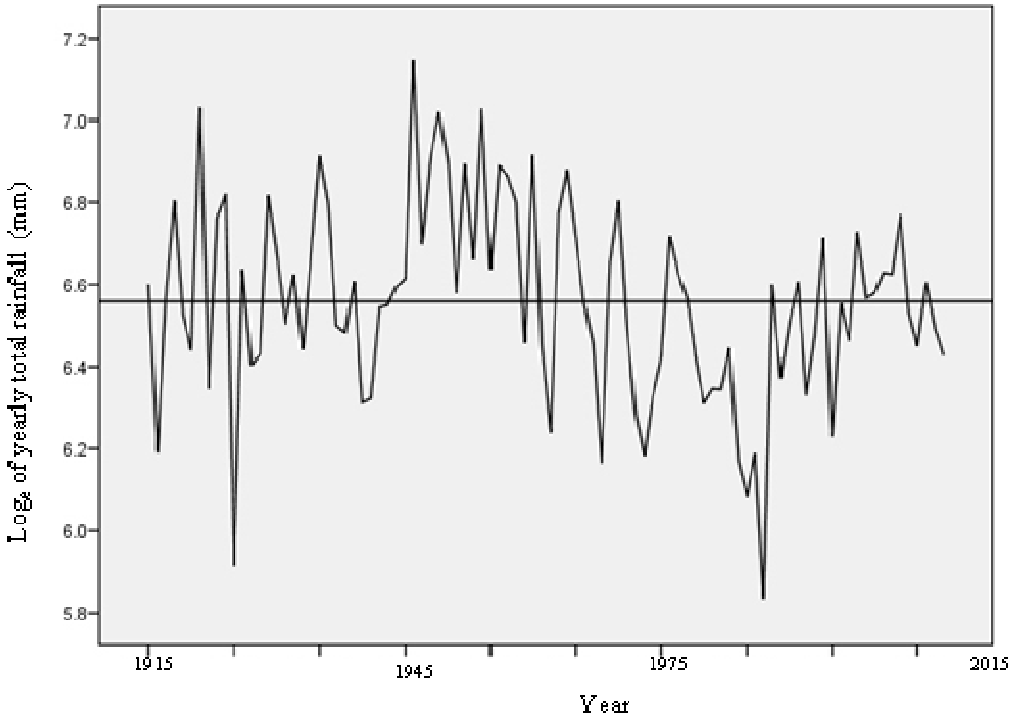

Figure 2. Sequence of yearly total rainfall

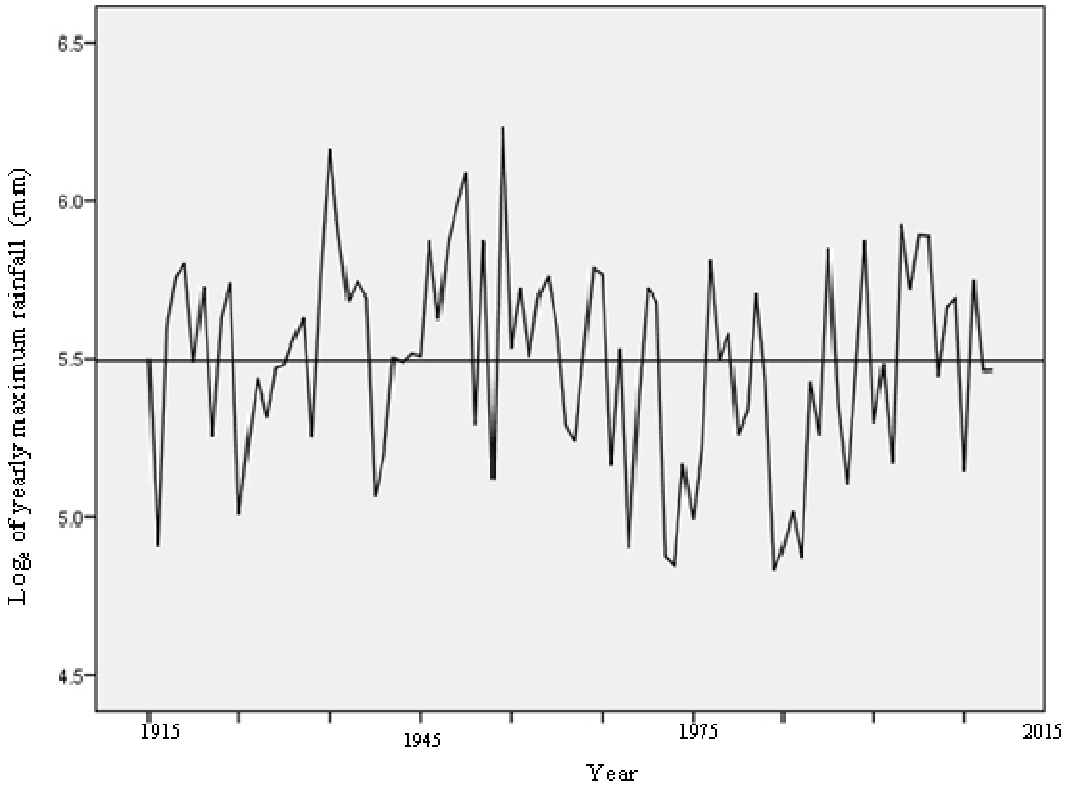

Figure 3. Sequence of yearly maximum rainfall

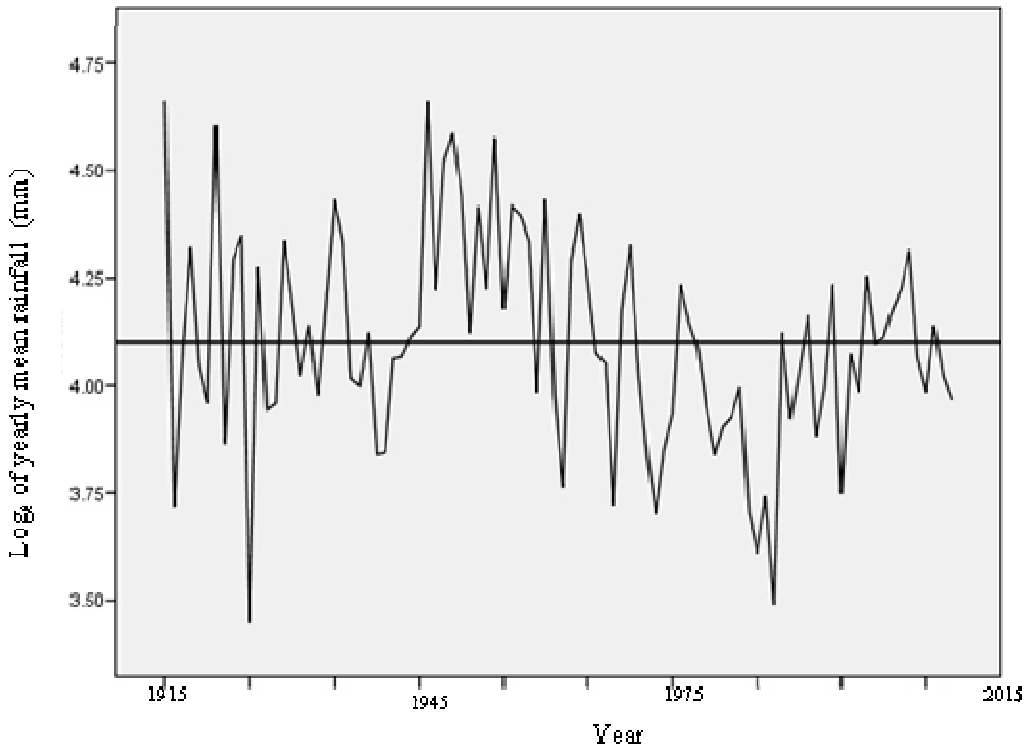

Figure 4. Sequence of yearly mean rainfall

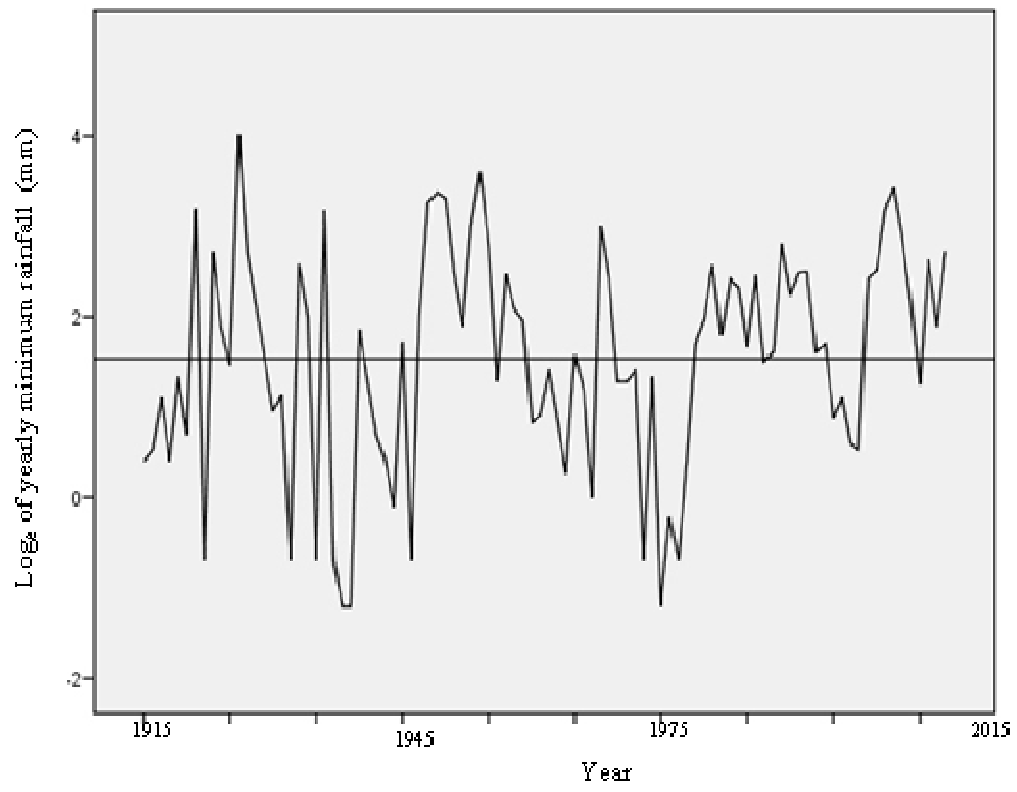

Figure 5. Sequence of yearly minimum rainfall

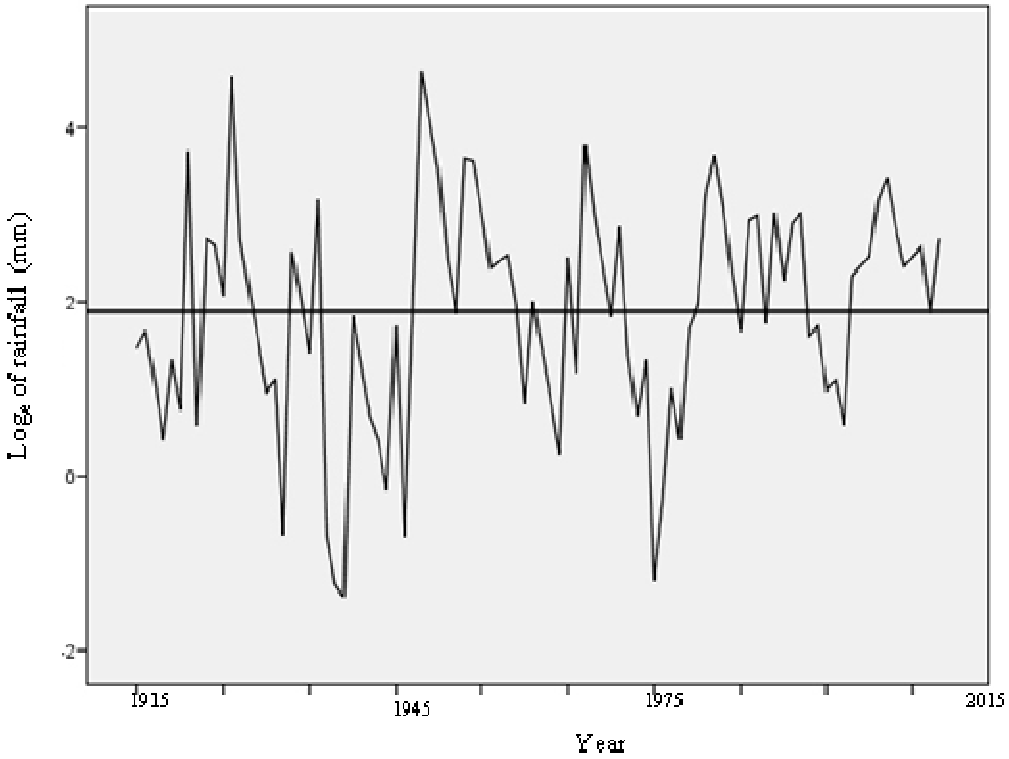

Figure 6. Sequence of rainfall in the month of April

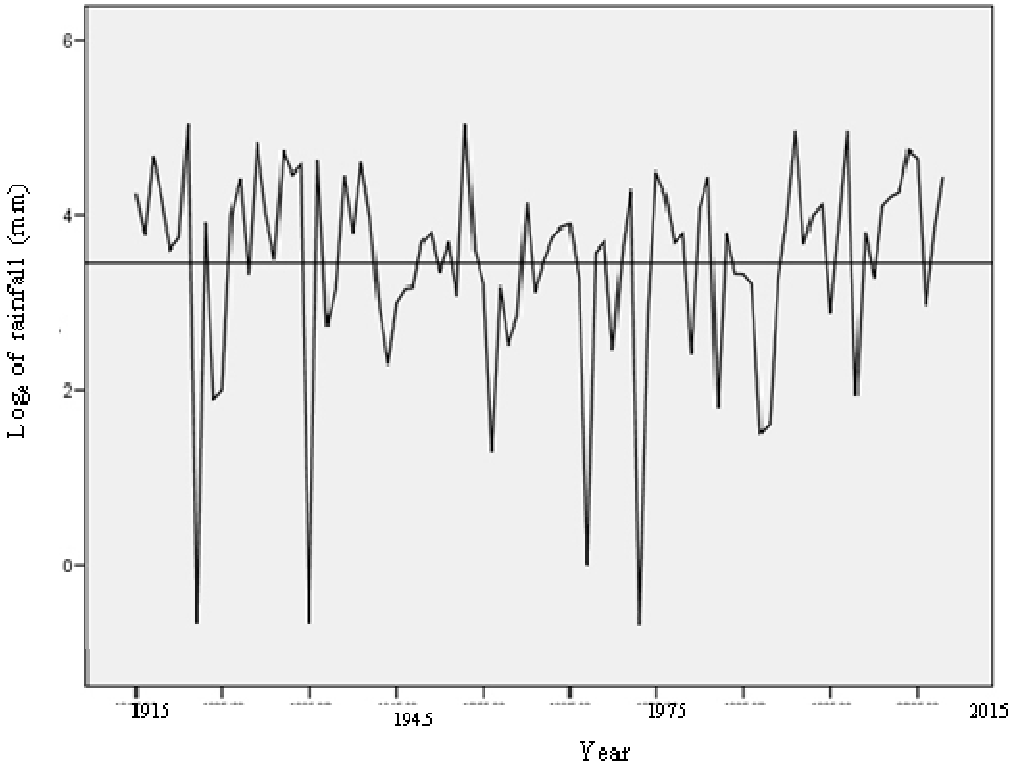

Figure 7. Sequence of rainfall in the month of May

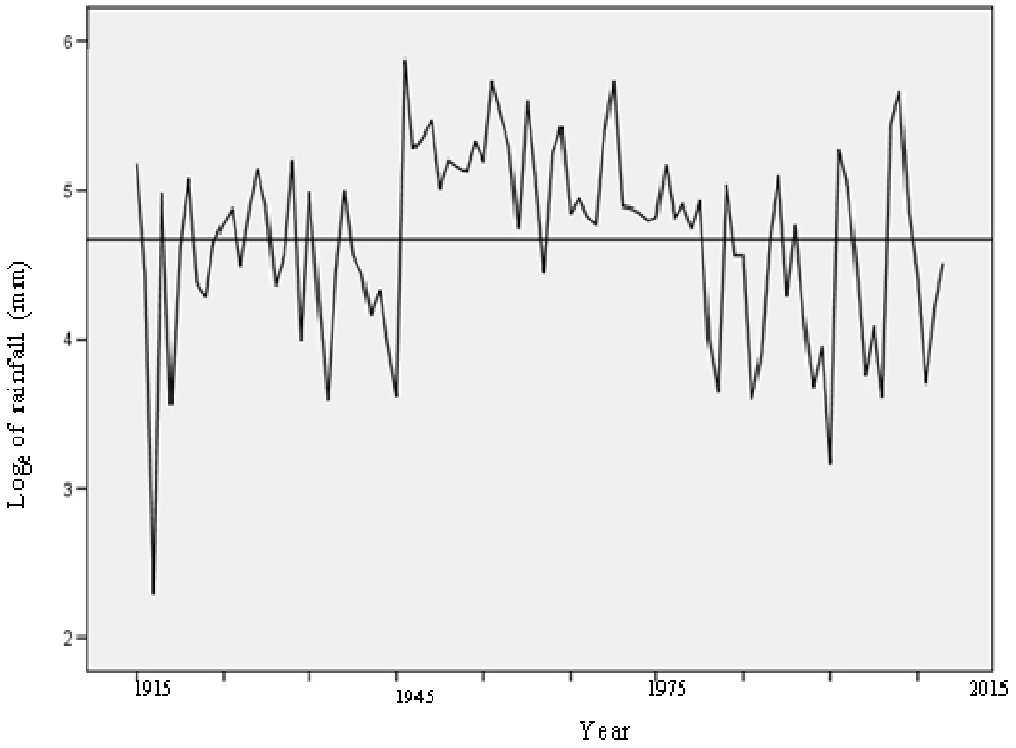

Figure 8. Sequence of rainfall in the month of June

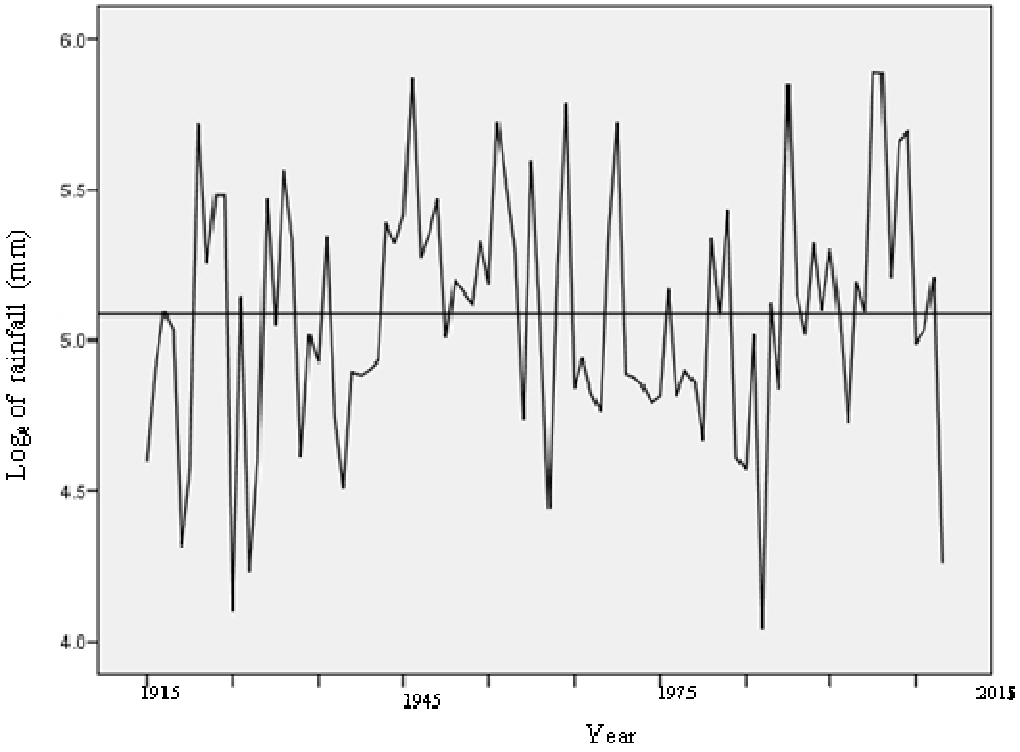

Figure 9. Sequence of rainfall in the month of July

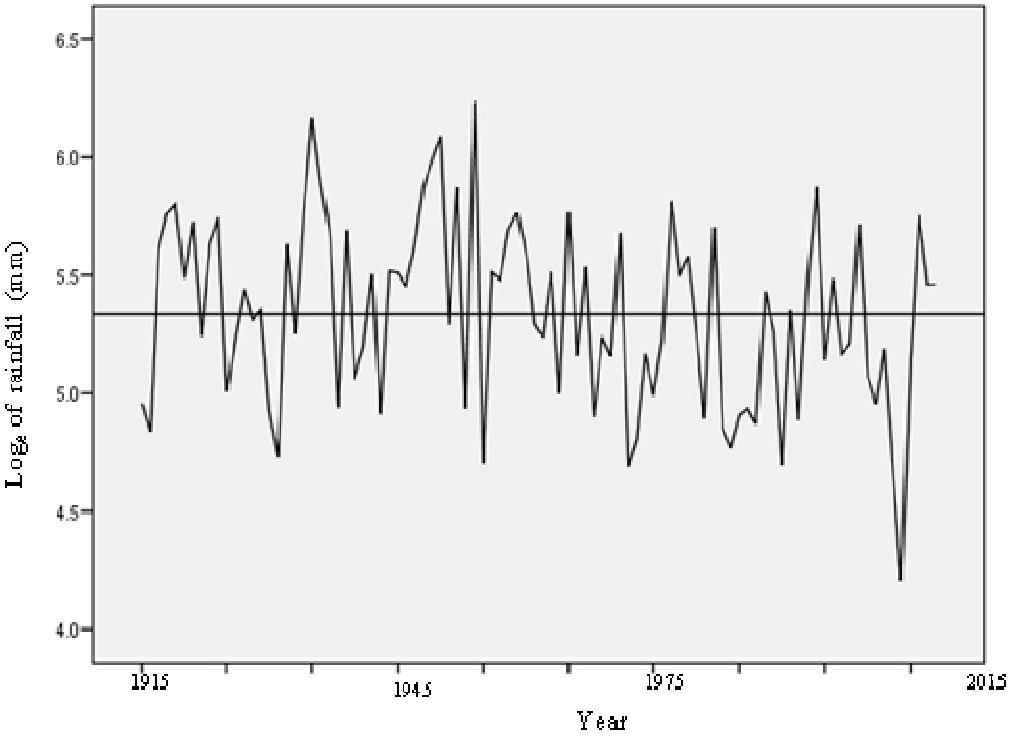

Figure 10. Sequence of rainfall in the month of August

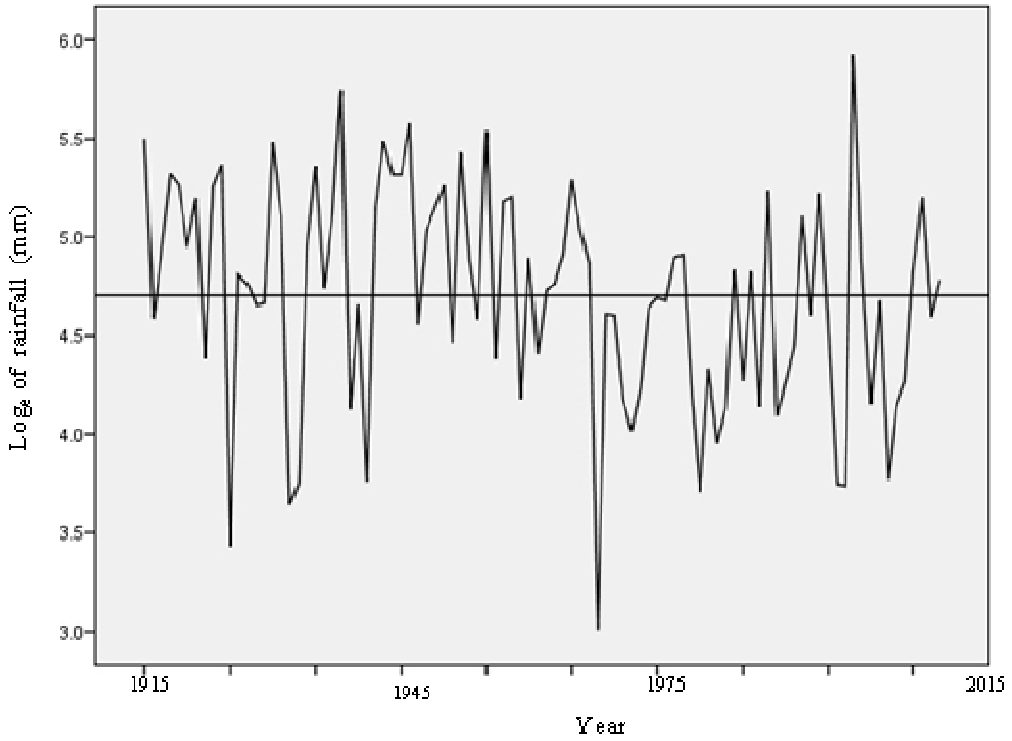

Figure 11. Sequence of rainfall in the month of September

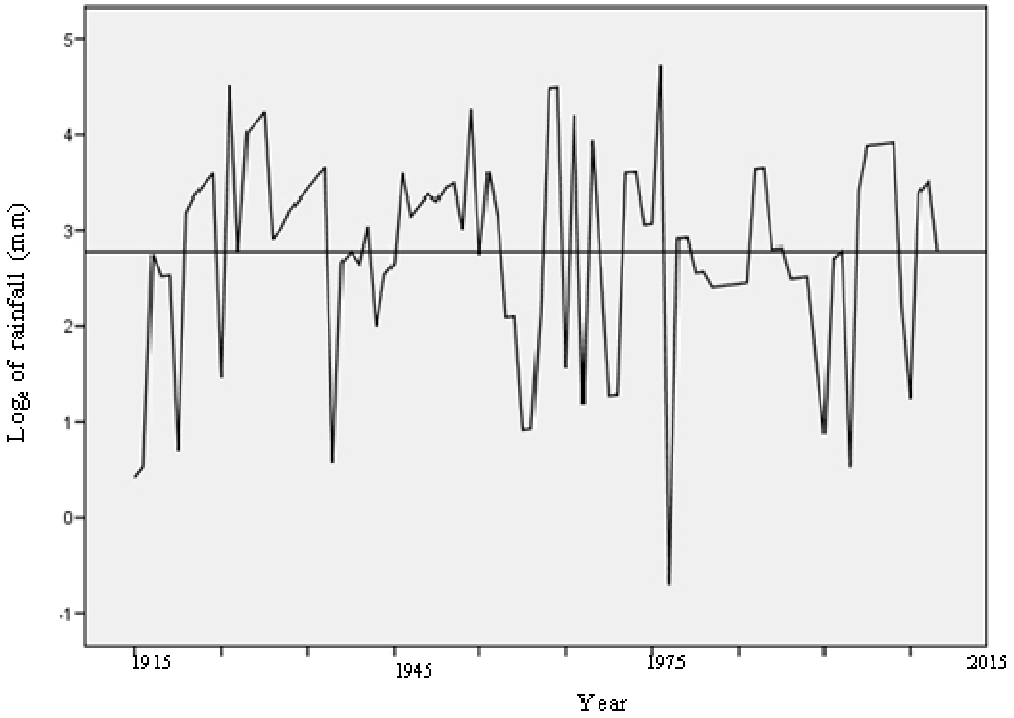

Figure 12. Sequence of rainfall in the month of October

The two major months July and August have downward trends of 1.196 mm/year and 0.709 mm/year respectively. These confirm lower overall downward trends in yearly total and mean rainfall than expected with downward trends in yearly maximum (4.459 mm/year) and yearly minimum rainfall (4.130 mm/year).

Sequence analyses of the rainfalls

Figures 2 – 12 present sequential values of the rainfalls in Sokoto. The figures apparently show decreasing trends in the rainfalls. Figures 2, 3 and 4 illustrate the downward trends appearance of the yearly total, maximum, minimum and mean rainfalls. In all these cases, the appearance of the strongest decreasing trend occurred between 1978 and 2008. From Figures 2 and 3 these sequences reveal that the pattern of the rainfall can be grouped into three categories as follows: 1915-1945 (moderate rainfall), 1946 – 1982 (excess rainfall) and 1983 -2008 (low drought). These groupings show that there is a decrease in the rainfall of the city in the last decades.

Figures 10 and 11 illustrate the downward trends appearance of the monthly rainfalls. In these figures, the appearance of the strongest decreasing trend occurred between 1978 and 2008. From Figures 2 and 3 these sequences reveal that the pattern of the rainfall can be grouped into three categories as follows: 1915-1945 (moderate rainfall), 1946 – 1982 (excess rainfall) and 1983 -2008 (low drought). These groupings show that there is a decrease in the rainfall of the city in the last decades. Figures 5,6,7,8,9 and 12 revealed no significant change in the monthly rainfalls. These can be attributed to many factors (these monthly are not the heavy rainy monthly and any other factors).

CONCLUSION

It can be concluded based on the study that:

- The rainfall pattern has changed in Sokoto,
- There are trends in the rainfalls pattern (yearly total, mean, maximum and minimum),
- Downward trends of the rainfall are statistically significant; and
- The trend revealed that the months August and September have downward trends

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